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MODERN VIEWS OF THE SUN

BY J. S. PLASKETT

(RETIRING PRESIDENT'S ADDRESS, ANNUAL MEETING, JANUARY 25, 1916)

A YEAR AGO I had the honor of giving you as my Presidential Address a résumé of the recent advances in our knowledge of the constitution of the sidereal universe. This year I have thought it desirable to consider one member only of the innumerable millions in that universe, and a comparatively insignificant member when compared in relative size and brightness with other stars; and yet a member which is to us all important, without whose presence and beneficent radiation all life on our globe would cease.

This, to us all important star, the sun, has in all times and all ages excited the keenest interest and wonder in mankind. It was in several races invoked as one of the deities who rule over mankind, and indeed, though perhaps not realized to the full by its followers, sun worship had a better basis for its existence, so far as man's material welfare is concerned, than any of the pagan religions.

In modern times we are only at the beginning in obtaining some idea of the real nature, constitution and influence of the

sun. Indeed, we need go no farther back than to the first Herschel to find that the sun was then considered a solid body essentially like the earth, surrounded by luminous, light-giving clouds, and that the sun-spots were mountains on this huge globe sticking up their heads through the clouds. It was probably not until the discovery of spectrum analysis, little more than half a century ago, that the true nature of the sun began to be dimly realized. Just as in the study of the stars, the last decade or so has seen more real advances in the study of the constitution, structure and motions of the sidereal universe than all preceding time, so the last twenty years of solar research have been more fruitful in teaching us the nature of this dominant orb of our system than all the labors and speculations of earlier periods.

And yet, just as in sidereal astronomy the advances of the present would have been impossible without the patient and painstaking observations of past generations, so in solar research we owe more than is generally realised to those who have carefully observed and faithfully recorded the visible phenomena of the sun, who have attempted to correlate them with terrestrial phenomena and who have advanced hypotheses, no matter if mistaken, to account for the observed facts.

The importance of the problem of the constitution of the sun is being more and more realized not only by astronomers and scientists, but by representative governing bodies and the intelligent public as well. This is indicated by the formation, within the last ten years or so, of the International Union for Co-operation in Solar Research, an association of the prominent astronomers, physicists and other scientific men of the world, interested in solar research, with the purpose of intelligently co-ordinating and combining the energies of all institutions into the most profitable channels of attack, and of preventing useless duplication of work. This organization has already been of immense advantage in standardizing and systematizing the methods of research and arranging for co-operative work in the various problems. It forms an authoritative international body whose decisions on systems of units, nomenclature, etc., shall be

final. The adoption of standard methods in the determination of wave-lengths and of a number of standards of wave-length for universal use, correct probably within one-thousandth of an Angström unit, or one part in five million, is one example of a decision which more than justifies its formation ; and a second is the adoption of the Harvard system of classification of stellar spectra for universal use.

The other instance of the dawning realization of the importance of the study of the sun has been the organization, under the auspices of the Carnegie Institution, of the Mt. Wilson Solar Observatory, also established just over ten years ago. This is probably the best equipped observatory in existence, with nearly every appliance that man can devise to assist in its special work on the sun, with the allied physical and astronomical problems. Under the able direction of Mr. Geo. E. Hale, our knowledge of the structure and movements of the sun's upper atmosphere has already been wonderfully extended and I shall have occasions frequently to refer to the discoveries made there.

In view of the limited time at my disposal it has seemed best to give you a brief account of present day views of the nature of the sun without attempting other than incidental reference to the historical development of the subject. To make the subject as comprehensible as possible to the layman, let us open it, even at the risk of some lack of sequence later, at the very beginning. If we look at the sun through smoked glass we see an intensely bright disc with a sharp circular boundary which is called the limb, and, sometimes, with dark spots on its surface. If we use a telescope of higher and higher power, of course with the intensity suitably diminished by shade glasses or other means, we find that the outer boundary still appears perfectly sharp and circular, that we see many more spots, that the surface of the sun, generally called the photosphere, is not uniformly bright but is mottled in a way that has led to its being called the rice grain structure, and that some parts near the limb and also often near spots are much brighter than the general surface, such parts being called faculæ. If these observations are continued we

would find, as was discovered about eighty years ago, that the numbers and sizes of the spots and faculæ varied, that they passed through a complete cycle of change, through maximum and minimum spottedness, in a little over eleven years. Another evident, and even obtrusive, fact of observation is that in addition to sending us a great deal of light we also receive a considerable amount of heat.

In addition to these observational facts let us recount a few well known dimensions. The sun, whose diameter is 865,000 miles, is situated nearly 93,000,000 miles from us. Its volume will evidently be $(865/8)^3$ or 1,306,000 times that of the earth. A simple dynamical calculation, based on the known times of revolution of the moon around the earth and of the earth-moon system around the sun, shows that the sun has 332,800 times the mass of the earth. The density of the earth which has been very accurately determined by the physicists is 5·52 times that of water and hence the sun is 1·41 times as heavy as an equal volume of water. If expressed in pounds the mass of the earth is 1317 followed by 22 ciphers and of the sun 438 followed by 28 ciphers. It readily follows that the attraction of the sun at its surface is 27·6 times that of the earth at its surface, and a man weighing 150 pounds would weigh over two tons on the sun and would be crushed to death under his own weight if he had not been already turned into vapor long before he reached the surface.

The sun being 93,000,000 miles from the earth, it is evident, even to the least observing and thoughtful, that it must be exceedingly bright and hot to give such striking evidence of these effects at that enormous distance. No doubt most of us have been present at a fire and have noticed how rapidly the heat diminished as we moved away, that, even if unpleasantly hot at a hundred yards, it was quite comfortable at two hundred. It seems quite reasonable to say that, if the sun radiates so much heat at 93,000,000 miles, it must be hotter than any temperature attainable on the earth.

It is evident that no direct method of determining the tem-

perature of the sun can be used, but there are several indirect methods, fortunately, by which we can obtain the temperture of the visible radiating surface, the photosphere. These are mostly too technical for a lecture of this kind, but one of them, perhaps, may be made to come within its range. Theory and experiment have shown that the radiation, the emission of heat and other energy, from a perfect radiator, (the sun is probably not quite a perfect radiator), varies as the fourth power of the temperature. This is known as Stefan's law and it is evident that if we can find the radiation sent out by the sun we can determine its temperature by extracting the fourth root of the radiation. The radiation or amount of energy emitted by the sun at the distance of the earth has been very carefully and accurately determined, (of this I shall have something to say later on), and has been found to amount to 1·95 calories per square centimetre per minute. This is the value outside our own atmosphere, but owing to the absorption of the latter less than two-thirds of this reaches the earth's surface. 1·95 calories means in plain language that if you have a little cube of water each side being a centimeter, two-fifths of an inch long, (less than a thimble full of water altogether) and if the sun is allowed to shine directly on one of these sides for one minute, and no heat is lost by reflection or otherwise, the temperature of the water would be raised 1°·95 C. or 3°·5 F. Put in another way the amonnt of heat reaching us from the sun is sufficient to raise the temperature of a layer of water two-fifths of an inch thick 3°·5 F in one minute. Knowing the amount per square centimenter 93,000,000 miles from the sun we get the total emission by multiplying 1·95 by the superficial area in square centimetres of a sphere 186,000,000 miles in diameter. Dividing this enormous amount by the superficial area of the sun we get the amount radiated per unit area, and applying the proper constants and extracting the fourth root we obtain the temperature of 5860° C. absolute. As the sun is probably not a perfect radiator its temperature would be higher than this figure and the other methods indicate a temperature not less than 6200° C., probably approaching 7000°. On the

ordinary Fahrenheit scale these are 10700 and 12100 degrees. Ordinary cast iron melts at 2000 and platinum at 3200 degrees, soyou willrealize that the photosphere must be composed of gases and vapors only.

Our ordinary methods of observation and analysis have shown us that the visible surface of the sun has a mottled appearance, is cyclically invaded by sun-spots and faculæ and is at such an excessively high temperature — nearly 12,000° F. — that it is unlikely to be composed of anything but gases and vapors.

To learn more of the structure of the photosphere and the upper solar atmosphere other methods of attack are necessary and let us now see what we can learn from the spectrograph and spectroheliograph and various auxiliary attachments of them.

Everyone, surely, in these days knows what a marvellous increase in our knowledge of the constitution and physical condition of the heavenly bodies has come to us by means of the spectroscope or spectrgraph, the latter being the modern form designed to photograph the spectrum. We all know, for example, that by comparing the positions of lines crossing the spectrum of any body with the positions of the lines in the spectra of the various elements, we can surely identify the elements present in the body. And, further, we know that if the lines crossing the spectrum are separate bright lines the body is composed of incandescent gases and vapors. If the lines are dark, then between the spectrograph and the bright body there is a layer of cooler gases, not necessarily cold, but only at a lower temperature than the bright body. If the spectrum is one continuous band of color without lines the body is an incandescent, solid or liquid, or possibly a gas under great pressure. Furthermore, any shift from the normal positions of any of these lines shows that the gas or vapor producing these lines is in motion towards or from us or is under pressure, motion and pressure shifts of lines being usually easily differentiated. The accuracy of modern spectrographs is so great that we can easily determine, on the sun at any rate, where there is plenty of light, a motion of the gases equal to the speed of a man running.

A little reflection will show how much these unique properties and possibilities of the spectrograph enable us to determine of the constitution, physical condition and motions in the photosphere and upper atmosphere of the sun usually called the chromosphere. The solar spectrum is apparently a continuous spectrum crossed by thousands of dark lines. The continuous part shows that the light-emitting part, the photosphere, is either incandescent, solid or liquid matter or else gaseous material under great pressure. The dark lines show that above the photosphere is a layer of gases and vapors at a lower temperature, sometimes called the reversing layer. A comparison of the positions of these lines with those of the terrestrial elements testifies absolutely to the presence of the vapors of some forty elements in this reversing layer, and possibly to a dozen more. Nevertheless, every scientific man believes that all the terrestrial elements are present in the sun and the lines of some of them do not show in the spectrum only because they give relatively weak spectra which are overpowered by the stronger spectra of those whose lines are visible.

When the exceedingly bright photosphere of the sun is covered by the moon at total solar eclipses, the spectrograph shows that the cooler gases in the reversing layer are really incandescent and at a high temperature. At the instant the photosphere is obscured the spectrum changes or flashes from a dark-line to a bright-line spectrum, every dark line practically being replaced in the same position, though not always of the same intensity, by a bright line. This, of course, is indubitable proof of the presence of thisl ayer of incandescent gases, while the length of the curved lines for the different elements enables a close estimate of the heights to which the vapors of these elements extend above the photosphere. The depth of this reversing layer or chromosphere is not uniform and the height to which the various gases ascend is different, depending in general upon the density, the heavier gases remaining at the lower levels and not often exceeding a height of 700 kms., about 450 miles. Hydrogen, calcium, helium, sodium and a few others

rise to much greater heights up to 10,000 or 15,000 kms., 6,000 to 9,000 miles. Rising higher still above the photosphere are the prominences which are apparently eruptions or outbursts of luminous gas which the spectrograph has shown are generally hydrogen and calcium. These were first seen at eclipses but can now be observed and photographed at any time. The prominences pass through a similar cycle to the spots and are apparently related in some way, although even when there are no spots the sun is never free from prominences. These prominences sometimes shoot up to the enormous height of two or three hundred thousand miles, occasionally reaching a velocity of two hundred miles a second. They are, to my mind, striking confirmation of the disturbed condition of the interior of the sun.

But, besides these tremendous eruptions, the spectroscope shows that the chromosphere, and probably also the photosphere, is rarely quiescent. Over and near sun-spots, for instance, the work of Evershed first showed by the displacement of the spectral lines that the vapors were in motion and this work has been further extended and rendered beautifully complete by the work of Hale and St. John, at Mt. Wilson. Before treating more particularly of the motions and structure of sun-spots, I wish to speak of an instrument by which the chromosphere can be photographed at different levels and in the light of different gases.

The principle of this instrument was independently brought out by Hale and Deslandres, about 1890, but the first spectroheliograph, as it is called, was constructed and used by Hale in 1891. This instrument, by which the distribution of the various gases and vapors at various levels in the sun's atmosphere can be photographed, is an ingenious application of the principle of the spectroscope. Many of the elements, especially calcium and hydrogen, give very strong and broad absorption lines in the sun's, spectrum. It occurred to Hale that by isolating the light from one of these lines in a spectrograph it might be possible that by suitably moving the sun and spectrograph relatively, to obtain a photograph of the sun in the light of this gas. Various forms of

spectroheliographs for accomplishing this aim have been devised but I need only describe the simplest.

If we have a large spectrograph with a slit as long as the diameter of the solar image, this will form a spectrum as wide as the sun crossed by lines as long as the solar diameter. If in the place of the photographic plate we place a metal plate with a slit in it, adjustable to any position, it will be possible for us to place this slit on any desired line in the solar spectrum. Evidently, under such circumstances, only the light from the gas or vapor producing this line can get through the second slit. A plate placed immediately behind this second slit will record the distribution of this particular luminous vapor over the particular narrow segment of the sun which is on the first slit. If then the plate and image of the sun are kept stationary and the spectrograph as a whole moved transversely across them, we will record successively on the plate successive segments of the solar disc in the light of the particular vapor whose line is on the second slit, or in other words we will obtain a photograph of the sun in the light of this particular vapor. This photograph will evidently record the distribution of this vapor, and this vapor only, over the sun's disc.

The spectroheliograph has been used almost continuously since its invention to obtain photographs of the sun in the light of calcium vapor, and the records of calcium flocculi, as the cloud-like formations covering the sun's surface are called, has been a valuable supplement to the direct photographs in ordinary light and clearly show the turbulent and ever changing state of the chromosphere. At Mt. Wilson the sun's surface has also frequently been photographed in the green, blue and violet lines of hydrogen and occasionally in iron lines. These photographs show an entirely different characteristic appearance and structure from each other and from the calcium spectroheliograms.

But probably the most striking spectroheliograms are those made in the light of the red line of hydrogen, $H\alpha$ as it is called. These have only been obtained at Mt. Wilson comparatively recently, after the introduction of specially stained plates highly

sensitive to red light. It is the red light of hydrogen which ascends to the highest levels in the chromosphere and which is the most prominent in eruptions and prominences. The spectroheliograms in this light have a characteristic appearance entirely different from those made in the blue or violet lines of hydrogen or in any other vapors. The most striking features about them are the curious whirls or twisted appearance of the gaseous matter around sun-spots, and the strong resemblance of these whirls to the lines of force around magnets led Hale to suspect that there might be a magnetic field around sun-spots.

This supposition was very natural as the relation between the spottedness of the sun and the activity of the earth's magnetism had long been recognized, the curves of sun-spot numbers and those representing the daily range in the declination and horizontal force corresponding in the most remarkable manner. Further it has been noticed that terrestrial magnetic storms are often nearly coincident with the central passage of a large sun-spot over the sun's disc.

To suspect that whirls in the $H\alpha$ spectroheliograms were indications of magnetic fields and to prove it were two entirely different matters. Even if such a field were possible of detection by magnetic methods on the earth, it would be impossible to definitely correlate such magnetic effects with any sun-spot showing whirls.

But here again the wonder-working powers of the spectroscope were brought into requisition by Hale in a most ingenious manner. About 1896, Zeeman discovered that most lines of the spectrum are separated into two components when the incandescent vapor producing these lines is in a strong magnetic field, and is observed by the spectroscope along the lines of force. With less powerful fields the lines are only widened. In addition to this doubling or widening the light is changed in character, it has become polarized, a curious one-sided form of light, and this polarization can be detected by suitable optical apparatus, such as a Nicol prism. When such a test was applied by Hale to some of the lines in the spectrum of a sun-spot it was found that they

behaved in exactly the same way under the analysis of the Nicol prism, as their terrestrial counterparts did when the vapor producing them was in a magnetic field.

Here then was incontestable proof that the curious whirls around sun-spots in the *Hα* spectroheliograms were of a magnetic character and that there was a magnetic field around sun-spots. By comparing the widening and the behavior of the sun-spot lines with their terrestrial counterparts under fields of varying strength, it was found at Mt. Wilson that the fields around sun-spots varied up to a maximum of 4500 gausses, which is about 7000 or 8000 times the strength of the earth's field but not as strong as the average electro-magnet. The polarity of the spots was found to vary in a somewhat irregular manner, large spots in northern and southern hemispheres being usually of opposite polarity and the same thing being true of the two main members of a spot group.

The strength of these fields is not sufficiently great to account for the magnetic storms on the earth which occasionally derange magnetic and telegraphic apparatus and which must be due to some more powerful and as yet unknown influence. But it seems evident that the striking similarity between the curves of spot numbers and the daily range of the terrestrial magnetic elements can be simply explained by the influence of the magnetic fields around sun-spots.

More recently Hale has shown, in a somewhat similar way, that, in addition to the fields surrounding spots, the sun has a general magnetic field similar to the earth, only about 80 times as strong. The magnetic poles of the sun coincide approximately with its axis of revolution, the north magnetic pole being towards the north as in the earth. The Zeeman displacements by so weak a field as this are exceedingly minute and require the greatest care and precision in measuring. These discoveries and measurements of the magnetic fields in the sun are striking examples of the wonderful experimental work carried on at Mt. Wilson and are of the utmost importance.

But they have been supplemented by much additional evi-

dence as to the physical conditions in and around spots. Considerably earlier than the discovery of the magnetic effects it was shown that the spot vapors were at considerably lower temperatures than those over the surrounding photosphere. This was done by a mass of cumulative evidence gathered by means of the spectrograph. It has long been known that the spot spectrum is different from the ordinary solar spectrum. Some of the lines are widened and strengthened, some are weakened, some are doubled as noted above, and many fine lines not present in the photospheric spectrum are present in spots. In the case of the widened and weakened lines it was found that these lines behaved in general in a similiar way in terrestrial spectra as in sun-spots when the temperature of the vapors producing them was reduced, thus showing that the spot vapors are at a lower temperature. It was further found that the numerous fine lines in the spot spectra were due to the formation of such compounds as magnesium and calcium hydride and titanium oxide, which can only exist at considerably lower temperatures than the photosphere. These facts formed convincing evidence that the vapors over sun-spots were at lower temperatures than over the surrounding photosphere.

As stated earlier, the radial motions of the vapors over sun-spots were first observed by Evershed, but his work has quite recently been much extended by St. John, at Mt. Wilson. These motions have, of course, been measured by the spectrograph from the displacements of the lines from their normal positions, and they vary for different elements and for different levels in the chromosphere. The hydrogen and calcium at the upper levels move inward at about two kilometres a second, this velocity diminishing as we go down and come to the heavier elements, finally turning into an outward motion, of the order of one-half a kilometre per second, for many of the lines of iron and other metals which lie at low levels. There seems to be a circulation of the vapors from above in and downward, and from below up and outward.

Based on these results, on the lower temperatures in the spot-

vapors and on the whirling motion and magnetic field around sun-spots, Hale has advanced a working hypothesis on sun-spots which includes all the data so far obtained and offers a reasonable explanation of the observed facts. According to this hypothesis a sun-spot is the result of an eruption or some other deep-seated cause, of which nothing is definitely known, which tends to produce rapid local upward movement of a column of gas from within the sun towards the surface of the photosphere. This column is given a whirling motion by differences in velocities or irregularities of some kind, producing a vortical motion much like a tornado or waterspout, the circulation in the spot being vertically upward and then outward along the photophere. Expansion produces cooling at the centre of the whirl or vortex and a comparatively dark cloud, the umbra of the sun-spot results. A rapid flow of negative ions sets in toward the cooler gases at the centre and these ions whirled in the vortex produce a magnetic field. Higher up in the solar atmosphere the descending gases, hydrogen and calcium, are drawn in toward the centre producing the whirls shown on the *Hα* spectroheliograms and giving the spectroscopic evidence of inward motion previously adduced.

From the researches I have been discussing, it is evident that we have a clear conception, probably not far from the truth, of conditions in the sun's atmosphere or chromosphere, of the distribution in height of the various elements, of their circulation in prominences, and especially in sun-spots, and we find that, perhaps except over sun-spots, they appear to be entirely gaseous and are in general at a high temperature, though, of course, (and this is evident from the dark line spectrum produced) in the outer layers considerably lower than the photosphere.

But hitherto, except for ascertaing that the temperature of the photosphere is not less than 6200° C. and possibly near 7000° C., 12000° F., we have not hazarded any hypothesis as to its constitution and physical condition, still less, as to the conditions below the photosphere in the interior of the sun which appear to be hopelessly beyond direct investigation. The com-

paratively low density of the sun, 1·4 times water, taken in conjunction with its enormous gravitational force, seems to point to a gaseous constitution of the interior. This view is strengthened by the enormous temperatures that must prevail in the inside of a globe whose outer visible surface is at a temperature of nearly 12000° F., which must increase with the depth. Any of these temperatures are probably above the critical temperature at which liquefaction can take place; and though it is possible that the enormous pressures and temperatures in the interior of the sun may in some way modify ordinary gaseous properties, it seems very unlikely that it can be either solid or liquid.

If the sun is wholly gaseous we have to answer the question: What causes the bright photosphere and what produces the apparently sharply-defined boundary between it and the upper atmosphere or chromosphere? The view probably held, until very recently at any rate, by most astronomers was, perhaps, most clearly expressed by Young, in his book on "The Sun," who says: "It seems almost impossible to doubt that the photosphere is a shell of clouds. As to the precise constitution of this shell, however, the form and magnitude of the component cloudlets, the chemical elements involved, and the temperature and pressure, there is room for a great deal of uncertainty and difference of opinion. The more common view apparently . . . . . is that the clouds are formed mainly by the condensation of the substances which are most conspicuous in the solar spectrum, such as iron and the other metals. As to the form of the clouds also, it has usually been assumed that, as a consequence of the ascending currents by which they are formed, they are columnar, their heights being much greater than their other dimensions." It is evident that the rice grain structure is readily explainable by this hypothesis, and the spots, faculæ, prominences and chromosphere do not offer any graver difficulties than would be met with in other hypothesis.

The question of temperature, however, is a serious objection as it is now practically certain that the radiating surface, the photosphere, the "shell of clouds" according to Young, is at a

greater temperature than 6000° C. Moissan placed the temperature of his electric furnace at 3500° C. and stated that all known elements were vaporized at that temperature. Under these conditions it does not seem possible to have a photosphere of condensed droplets of metals and other explanations of its nature have been advanced.

The theory of Schmidt explains the sharp boundary of the photosphere by assuming that it is wholly gaseous. Owing to the curvature of the rays of light by refraction through the solar atmosphere, whose density must rapidly increase with the depth, the refraction would become so great at a certain diameter of the sun that the line of sight from the earth would be curved sufficiently to pass around and around the sun. At a greater diameter the line of sight would pass through the outer layers of gas and emerge on the other side. The sharply-defined limb would evidently be the limiting diameter where the refraction would be such as to cause the line of sight to foliow around the circumference. Although this optical hypothesis gives a reasonable explanation of the photosphere, matters are considerably complicated when we attempt to explain sun-spots, and it has not received much acceptance from observers of solar phenomena.

Julius has also advanced an interesting theory which explains solar phenomena by the effects of anomalous dispersion, and though astronomers are willing to admit that anomalous dispersion may have some place in modifying the observed effects, Julius's views have received even less acceptance than Schmidt's.

Abbot in his recent book, 1911, on "The Sun" has elaborated a theory, first generally stated by Secchi and contributed to by Schuster and Schwarzschild, which seems to explain in a satisfactory manner most solar phenomena. In this theory it is assumed that the sun, except perhaps in sun-spots, is wholly gaseous and vaporous, the photosphere being too hot to contain solids or liquids. Further, the density of the gases rapidly diminishes and their temperature rapidly falls from within outwards across the apparent boundary of the sun. Abbot explains

the sharp boundary of the photosphere by the molecular scattering of the light in passing through the layers of gases and vapors surrounding the sun, and computes, based on the work of Rayleigh and Schuster, that this gaseous scattering would prevent us seeing further than 5000 miles into the interior when looking at the centre of the sun, and to less than 500 miles when looking at the limb. This latter amount is sufficiently small, about one second of arc, to make the limb appear sharply defined.

He answers the objections of the advocates of a cloudy photosphere that the enormous radiation into space must so cool the outer layers as to condense vapors, by stating that the visible photosphere, the "cloudy" layer, is certainly above 6000° C., at which temperature no vapors can condense, and that the conveyance of heat from the interior is so rapid as to maintain the temperature at this high level.

Another argument against the cloud theory that has occurred to me may be interpolated here. If the temperature of the cloudy layer is low enough to condense some of the vapors, why are not these same vapors in the reversing layer, which produce the dark lines in the solar spectrum and are admittedly at a lower temperature and higher level, also condensed. Furthermore, the lighter non-condensible elements, such as hydrogen and helium, which are admittedly incandescent to the height of about 10,000 miles, may serve as a sort of intermediary between the high temperature of the photosphere and the low temperature of space, and maintain the temperatures of the lower level metallic vapors above the condensing point.

The rice grain structure of the photosphere is easily explained on this hypothesis by differences of temperature caused by irregularities of convection and radiation, while the fundamentally continuous character of the spectrum of the photosphere can be produced by gases in thick layers under high pressures. The darkening towards the limb follows naturally as we see further into the interior at the centre of the sun and hence to layers of higher tempesature and brighter, than at the limb.

The phenomena of the absorption lines in the solar spectrum, of the reversing layer, upper chromosphere and prominences, as well as of the corona, of which time permits only the mention, are at least as readily explainable on this hypothesis as any other, and the same is true of sun-spots of which a working hypothesis was given above.

What we have hitherto said gives us a clear idea of the mechanism of the sun's outer atmosphere, of its distribution, currents and motions, but tells us nothing as to the fundamental cause of the eruptions which produce spots and prominences, nor as to the reason for the cyclical changes which they go through. Further, the change in the speed of rotation for different latitudes, and, still more remarkable, the variation of this speed, which now seems to be well established, remains a mystery. Various theories by Secchi, Faye, Oppolzer, Halm, Emden and others have been advanced to account for these phenomena, but in view of our absolute lack of direct knowledge of what goes on below the photosphere, it is evident that, even if time permitted, little of definite value could be said of the nature and cause of these deep-seated phenomena.

We have hitherto spoken only incidentally of what is to us certainly the most important function of the sun, its radiating power, by which all life on our globe is sustained. The determination of the quantity of heat reaching the earth from the sun has long interested physicists and astronomers, but it is only within comparatively recent years that accurate measurements of this quantity have been made. It is chiefly to the labors of Langley and his successor in this work, Abbot, that we now know that the average radiation reaching the earth's atmosphere is nearly two calories per square centimetre per minute. Somewhat more than one-third of this quantity is absorbed by the earth's atmosphere and the other two-thirds reaches the surface. More recently Abbot has shown, by the most careful and accurate work, that the mean yearly values of this radiation vary over a range of perhaps five per cent., being greater at sun-spot maximum than at minimum. In addition to this long-period

range, there seem to be short-period oscillations, more or less irregular, of a somewhat greater magnitude, varying altogether between 1·8 and 2·0 calories, but over any single short period the range not exceeding five per cent. It is easy to correlate the long period changes with the variation of the solar activity but as to their actual fundamental cause, we are as much at sea as in the case of other solar phenomena. It will be interesting to see whether these changes in radiation, especially the short-period ones, can be connected with meteorological changes and whether they can be used in weather prediction.

If the sun is emitting energy at the rate of 2 calories per square centimetre per minute at the distance of the earth, it is evident that its total emission will be twice the area in square centimetres of the surface of a sphere 186,000,000 miles in diameter or that the sun radiates 525 followed by 25 ciphers calories per minute.

If the sun were a body cooling without any means of replenishing its stores of heat, this radiation would cause it to fall in temperature about 1°·4 C. per year, which would be about 3000° C. within historic times. As the radiation varies with the fourth power of the temperature, the earth 2000 years ago would have been receiving five times as much heat as at present, which is manifestly not the case.

What then maintains the energy of the sun at a constant or nearly constant rate of emission? Some idea of the enormous quantity of heat given out will be evident when it is stated that it would require the burning over the whole solar surface of a layer of anthracite coal 23 feet thick every hour. At this rate, if the sun were made entirely of carbon, it would not have lasted five thousand years.

A theory brought forward by Mayer, about the middle of the last century, assumed that the solar energy was maintained by the falling of meteorites into the sun. Such bodies would reach the sun with a velocity of about 400 miles per second and would generate on impact more than 6000 times the heat of an equal weight of coal. To maintain the sun's heat there should

fall on every square yard of the sun's surface about 2 pounds every hour. This would increase the solar diameter about one second of arc in 5000 years, a quantity impossible to detect probably in less than 2000 or 3000 years. But the increase in mass of the sun would affect the length of the year, shortening it by about one-eighth of its value in 2000 years. Furthermore, sufficient meteoric matter in the solar system to maintain the sun's heat would cause the earth to receive ten million times as much as at present and either one of these deductions is sufficient to cause the rejection of the theory.

The theory now generally accepted as being the principal cause in the maintenance of the sun's heat — its shrinkage under its own gravitational force and the transformation of the work done by this shrinkage into heat — was first proposed by Helmholtz, about 1853. It has been computed by various writers that a shrinkage of about 250 feet per year in the diameter is now sufficient to make up for the loss by radiation. Newcomb calculated that it will require to shrink to about one-half its present size to maintain the present rate of radiation for 7,000,000 years. Further, if the original nebula, which on condensing, formed the sun originally filled a sphere whose diameter was that of Neptune's orbit, it would have furnished about 25,000,000 times as much energy as the sun now loses in a year.

If the rate of giving out energy had been constant this would make a period of 25,000,000 years during which the earth had been receiving heat as at present. In various ways geologists have estimated the age of the earth as somewhere between 50,000,000 and more than 100,000,000 years, with most of them inclining to the longer period, and the difficulty arises of explaining the discrepancy between the 25,000,000 years and the much longer time required for geological processes on the earth.

It was thought when radio-activity was discovered that this hitherto unknown source of energy might serve to bridge over the gap between the astronomical and geological epoch. But it seems doubtful at present and is not yet definitely settled

whether radio-active processes are or have been, considerable sources of solar energy.

It seems to me quite probable that in the earlier stages of the sun's and earth's history the greater internal heat of the latter and possibly different atmospheric conditions may have markedly accelerated the geological processes, while at the same time the sun may not have been radiating at so rapid a rate. Its greater diameter in early ages would also, probably, affect matters favorably so far as reconciling the two views are concerned. It is possible that by such means the life of the sun could perhaps be extended to fit the geological estimates or the latter may by later researches be diminished. However this may be, the contraction theory seems the only one in sight for accounting for the maintenance of the solar radiation.

I have by no means been able, in this paper, to cover even a small fraction of the ground required to adequately treat this subject, but I hope sufficient has been said to give you some idea of the most recent views on the constitution of our luminary and to show you that we are, probably, only on the threshold of what we may hope to learn by improved methods about this, to us, most important star of the universe.

LIGHTNING

ITS NATURE, AND THE EFFICIENCY AND METHODS OF LIGHTNING PROTECTION

By Wm. H. Day

VARIOUS hypotheses have been advanced as to the origin of the electric charge in the thunder-cloud. Perhaps the most commonly accepted have been: (1) That the friction of air as the wind drives against the earth, fences, buildings, trees, etc., electrifies the air positively and the earth and objects on it negatively. (2) That evaporation produces a positive charge in the vapor and a negative charge on the earth. If we recall the conditions which precede most thunderstorms two words will describe them, *viz.*, "calm," and "sultry," *i. e.*, warm with high humidity. The former offsets the friction and the latter the evaporation theory — when it is calm there is little friction, when sultry, little evaporation.

In the years 1908 and 1909, Dr. G. C. Simpson, of the Indian Meteorological Department, endeavored to produce electrification of air by various methods. Strong currents were blown against obstacles, rapid evaporation was caused, alternate freezing and thawing was produced but no sign of electrification was detected. Finally, an experiment was devised whereby a current of air of varying velocity could be driven upward through a jet of falling distilled water. When the air velocity was such as to break the water into spray, electrification was produced, the lower portion of the cloud of spray, being positively charged and the upper portion negatively. From this experiment Simpson evolved his explanation of the thunderstorm, briefly as follows:

There are upward currents in the forming thunder-cloud — we can see this by the characteristic movements of the parts of the cloud in the distance. Moreover, absence of winds, allowing the air

to become heated to high temperatures are the conditions necessary to produce these upward currents. When the air becomes sufficiently heated it begins to rise of its own initiative, or it may be forced up by an under-running layer of cooler air. As the current reaches the higher strata it spreads out and lessens in velocity. By this time, on account of the high moisture content, rain drops form and begin to fall. As they descend they encounter the swifter current below, which breaks them into spray, some of whose particles are positively charged and others negatively, just as in the laboratory experiment. The negative earth-charge attracts the former and repels the latter, hence the positively charged particles range themselves on the lower confines of the spray, and the negatively charged ones on the upper confines. Once the initial charge is produced the drops descending to meet the upward current are doubtless charged, induction assists, and the potential increases very rapidly as the process is repeated again and again.

Such in merest outline is Simpson's rational hypothesis, which seems sufficient to explain all the known phenomena, and which is at the same time supported by the evidence of laboratory experiment. Those wishing to study the matter are referred to a most exhaustive treatise on "The Thundstorm and Its Phenomena," by Professor W. J. Humphreys, in the *Journal of the Franklin Institute* or the *U. S. Monthly Weather Review*.

Once the potential of the thunder-cloud is great enough, flashes of lightning begin. The discharge is a progressive one, ionizing its path as it proceeds. It is often referred to as oscillatory, like that of a Leyden jar, but as yet there seems to be no certain evidence that lightning discharges are ever distinctly oscillatory, Indeed DeBlois' investigations (*Proceedings American Institute Electrical Engineers*, April, 1914,) seem to indicate that the discharges are undirectional, although sometimes successive discharges follow one another along the same path in the same direction. In 50 flashes observed there were 38 single and 12 multple ones.

Franklin demonstrated that lightning is caused by a dis-

charge of electricity, and advanced the claim that consequently it is feasible to protect buildings against lightning. Since the current producing the flash must obey the laws of electricity, it should be possible to conduct it harmlessly to the ground along a metal cable, just as to-day the tremendous electric power from Niagara Falls is conducted along the transmission lines. Moreover static electricity, such as exists in the thunder-cloud and on the earth beneath it, leaks off points, making it impossible for a conductor equipped with points to remain charged. Consequently it should be possible in many cases to prevent strokes to buildings by having them equipped with metallic points which will allow leakage and cause the earth and cloud charges to neutralize each other. Since Franklin's time the lightning rod has run the gamut of popular favor followed by popular condemnation and rejection. Scientists as a class, probably never lost faith in them.

About the year 1901 the Department of Physics at the Ontario Agricultural College began a study to determine whether lightning rods were actually of any value as protection against lightning. The first question we asked ourselves was this: "If a rodded building is struck, is it as likely to be burned as an unrodded one which is struck?" Reports were received from a number of selected observers in the various counties, also from insurance companies, but a still greater number were clipped from the daily and weekly papers, and in all cases where the owner's address was learned, he was written to for a personal report. In the ten years from 1901 to 1910 reports were received covering 599 buildings that were struck by lightning. Of these 317 were burned, or 53·6 per cent. This percentage is higher than obtains generally, because most of our reports originated in the newspapers, and naturally it is chiefly the severe strokes that are thus reported. Amongst that 599 there were only 18 rodded buildings, and of these only three were burned, which is one in six or 16·6 per cent., as against 53·6. Hence, we concluded that an unrodded building, if struck, is more than three times as likely to be burned as a rodded one.

So much for rods carrying off strokes. How could we determine whether rods prevent buildings from being struck? If 1,000 rodded buildings escaped damage during a storm, how could we ascertain whether some of them would have been damaged if not rodded? We knew that amongst 599 buildings that were struck there were only 18 rodded ones, which is just 3 per cent. If we knew what percentage of farm buildings in Ontario were rodded, that would settle the question. If rods neither prevent nor induce strokes, then the percentage of rodded buildings amongst those struck should be just the same as the percentage of rodded buildings in Ontario. If the rods cause strokes then, proportionally, more rodded ones would be struck than unrodded, but if they prevent strokes, then proportionally less.

After following numerous clues that failed during the years 1906 to 1911, we finally induced eighteen insurance companies to keep special records for us during the year 1912. From the reports of these eighteen companies, covering more than one-quarter of the Province, it was found that in every 200 farm buildings insured, 42 were rodded, which is 21 per cent., but out of every 200 farm buildings struck by lightning only 3 were rodded — we should have expected 42 if the rods were no good.

Or stating it in another way, in every 7,000 *unrodded* farm buildings insured by these companies, 37 were struck by lightning, of which several were burned; but out of every 7,000 *rodded* ones insured, only 2 were struck (and damaged only)— we should have expected 37 if the rods were no good, hence, in Ontario as rods are installed, an unrodded building is 18½ times as likely to be struck as a rodded one is. These results cover all kinds of rods used in Ontario and doubtless include some improper rodding. To prevent damage in 35 cases out of an expectancy of 37 means an efficiency of 94½ per cent.

During 1913 the insurance companies continued their most valuable co-operation. Forty of them kept special records for us, sixteen being able to give us reports complete in every particular. They represented twelve different counties, and of the

buildings insured by them 26·2 per cent were reported as rodded, showing an increase over 1912 of 5·2 per cent. The total number of claims paid for lightning damage to buildings was 193, of which 36 were burned, amounting in all to $40,904.53. If the rods had no effect — good or bad — we would have expected 26·2 per cent. of the strokes and damage would have been on rodded buildings, which would mean 50 strokes and $10,715.98, while as a matter of fact the number of strokes to rodded buildings was only 8, and the damage only $57.64, a saving of $10,658.34. To save this amount out of an expectancy of $10,715.98 shows an efficiency of 99·5 per cent.

Of the other twenty-four companies, fifteen were located in the counties above referred to and nine in other counties, in some of which the percentage of rodded buildings is exceptionally high, a fact which we know by personal inspection, so we may safely say that in the whole forty companies the rodded buildings total 26·2 per cent. or more.

Taking the whole forty companies together, there were 621 lightning damages totalling $113,459.89. 110 of these buildings were burned. We should have expected 26·2 per cent. of the strokes and damage to be on rodded buildings. This would have given 163 strokes and a loss of $29,726.49. As a matter of fact, only 16 rodded buildings were struck and the loss was $3,917.09, so the rods saved $25,809.40, out of an expected loss of $29,726.49, showing an efficiency of 86·8 per cent. Since Mr. Currie's fire was directly due to the absence of ground rods at a vital point, it seems only fair to consider this barn as not rodded. If this is done the efficiency of the rods in 1913 would be 92 0 per cent.

Perhaps, some may say: "But maybe those rodded buildings expected to be struck were actually struck, and the rods carried off the strokes harmlessly and so the insurance companies, having no claim to pay, have no record of those strokes." If any take this ground, well and good, because it is an admission that the rods in one way or another brought about the desired result, *viz.*, to save buildings from damage by lightning.

It may be well, however, to remark that in all probability

there is some ground for the objection. Probably more than two of the 37 rodded buildings expected to be struck in 1912 were actually struck, and of those expected to be struck in 1913, probably more than 16 were actually struck, and the rods carried off the current without damage, indeed, without any trace of the strokes remaining to show that they ever occurred. The exact comparative value of the *saving* and *preventive* functions of rods we are not able to determine, but these facts together with scientific considerations lead us to conclude that the preventive function is by far the more important.

In order to ascertain if similar results were being obtained elsewhere, the writer visited Iowa and Michigan, where it was reported some advanced work in rodding had been done.

In Iowa continuous records were available for eight years, though strange to say, the method, now so simple, of calculating the efficiency had not been worked out. For the years 1905-1912 inclusive, a large number of insurance companies doing farm business only, had reported the percentage of rodded buildings covered by their risks, and also the claims paid on rodded and unrodded buildings. The highest number of companies reporting in any one year was 68 and the lowest 46, the average being 55. These companies report that about 50 per cent. of all their risks are rodded. From the reports the following facts are gleaned:

The total lightning claims paid by all these companies for the whole eight years on *rodded* buildings was only $4,464.30, which is an average of $10.15 per company per year. On *unrodded* buildings, however, they paid lightning claims amounting to the large sum of $341,065.32, which is an average of $775.15 per company per year — and the number of unrodded buildings insured was the same as the number of rodded ones. Comparing $775.15 with $10.15 we see that for every $1 paid on rodded buildings $76 was paid on unrodded ones, or the rods save $75 out of an expected loss of $76, if the buildings had not been rodded. This shows an efficience of 98·7 per cent. It is

probable that some improper rodding is included, as the rods were not subject to inspection.

The case is not yet complete, however, as in both Ontario and Iowa the reports cover some defective rodding. The true efficiency of lightning rods can only be determined when we consider a large number of properly rodded buildings.

In Michigan the writer was fortunate enough to procure such a report. But here too, as in Iowa, the efficiency of rods had not yet been calculated. The Farmers' Mutual Lightning Protected Insurance Company of Michigan, as its name implies, insures only rodded buildings, and that only after the Company's inspectors have carefully examined the rodding and approved of it. During 1909-1912, inclusive, in a business which for the four years totalled $55,172,075 risk, this company paid only $32 for damage to buildings by lightning, in three small claims, all traceable to defects in rodding which were overlooked by the Company's inspector, or had been produced subsequent to the rodding, by installing telephones without properly protecting them from strokes which might follow the wires.

The Patrons' Mutual Fire Insurance Company, which also does business all over the State of Michigan, insures both rodded and unrodded buildings. In the same four years, on a total risk of $59,567,272 this company paid lightning damages on buildings to the extent of $32,268.78, which is 1008 times as much as the protected company paid. In conversation, the Secretary of the Patrons' Company said, that in eleven years they had only had three small claims for lightning damage on rodded buildings, all the rest of their lightning damage being on unrodded ones. They reported 20 per cent. of their risks rodded. Deducting these rodded risks, we see that the $32,269 damage occurred on unrodded risks amounting to $47,753,818. At this rate the loss on $55,172,075 of unrodded risks, the same risk as the Protected Company had, would be $37,282, which is 1168 times as great as the loss on the same amount of properly rodded risks. Thus we see that when the damage to properly rodded buildings amounted to $1, the damage to unrodded ones amounted to $1168, or in

other words, rods saved $1167 out of an expected loss of $11[illegible], indicating an efficiency of 99·91 per cent. or a saving of $999.10 out of an expected loss of $1,000.

The Protected Mutual began business in October, 1908. Its risks to December, 1913, totalled nearly $35,000,000, while the Patrons' Mutual, in the same time, has only increased from $12,000,000 to $19,000,000. So phenomenal had been the success of the Protected Company that it began to draw members rapidly from the other companies. To them this meant ultimate death, so some of them began to carry their rodded and unrodded buildings in separate classes, each class being assessed for its own losses, and now nearly every mutual insurance company in the State of Michigan is carrying rodded and unrodded classes, or preparing to do so. The Patrons' Mutual, referred to above, had been doing so for five years, and its assessments per $1000 of risk had been as follows:

Year	Assessment per $1000 of risk.	
	Unrodded	Rodded
1909	$2.50	$1.50
1910	3.33	2.50
1911	2.50	1.87½
1912	3.33	2.00
1913	3.33	2.00

During the same five years the assessments of the Protected Company had been:

Year	Assessment per $1000 risk
1909 } Together 1910 }	$2.00
1911	1.30
1912	1.20
1913	2.00

While in Michigan, the writer spent two days at Lansing, in the Department of Insurance, examining the original reports of ten different companies, including the two above mentioned, and

compiling data therefrom. Previous to 1913 five of them were carrying both rodded and unrodded classes. I found the average assessment by these five companies on unrodded buildings to be $2.96 per $1000 of risk, while the average on their rodded buildings was $1.89, showing a difference of $1.07 per $1000 in favor of the rodded buildings. If we calculate that difference in percentage we find that the assessment on rodded buildings was 36½ per cent. less than on unrodded ones. Or taking the rodded assessment as the standard, then the assessment on the unrodded ones was 56·6 per cent. greater than on the rodded ones. Now this is not theory or science — it is the practical experience of cool-headed insurance men and cautious farmers in mutual insurance companies, where the assessment is in direct proportion to the losses incurred. This is the protective value of lightning rods reduced to dollars and cents in insurance rates.

Since the publication of the results of our investigations, similar studies have been presented by Professor J. Warren Smith, of the College of Agriculture, Columbus, Ohio. and from reports of a larger number of insurance companies doing business in fifteen different states, he finds the efficiency of lightning rods to be 90 per cent. which is within a small amount of the general result we obtained in Ontario. To one familiar with the facts there can be no further doubt that lightning rods are highly efficient, notwithstanding much defective installation ; and that with proper installation they are practically absolute protection against damage by lightning.

KIND OF ROD

The type of rod seems to make no material difference in efficiency provided it is properly installed and in a good state of repair. From the practical standpoint any metal seems to have plenty of conductivity for satisfactory results. In the last analysis, therefore, it is a question of durability, and also whether the cable is suitable to permit of proper joints and connections with metallic portions of the structure being easily made. Judged by these practical requirements, copper is pre-eminently the material for

rodding purposes. We have samples of iron cables which rusted off at the ground surface in from ten to fifteen years. The shortest lived kind of rod that has come under our observation is one composed of a sheet of copper wrapped around an iron centre. We have samples of this kind in which the iron has almost completely turned to rust in less than eight years. Last year we received a sample of this kind which had been installed the previous autumn and it was considerably rusted even in that short time. Numerous hollow cables so designed to secure large surface have been on the market for many years. There seems to be no special virtue in this type. The high efficiency of 98·7 per cent. in Iowa and 99·9 per cent. in Michigan was obtained largely on cables composed of solid wires. Larger surfaced cables could not do better, particularly since we observe that in cases where injury occurs it is usually attributable to inferior systems or defective installation. Besides, hollow cables are not as substantial and durable as those composed of strands.

GROUND CONNECTIONS

The most common method of making groundings on farm buildings is the following: A drill is forced into the ground, driven if necessary, to a depth of about eight feet in order to reach permanent moisture, and when the drill is withdrawn the end of the cable is slipped down to the bottom of the hole. As this method gives efficiency as high as 99·9 per cent. the small deficiency being reported as due to causes other than imperfect grounding, there seems to be no need, on farm buildings at least, for the elaborate groundings sometimes advocated.

To enter into the why and wherefore of every direction for rodding buildings, would require much more space than at my disposal. Suffice it to append a summary. Those wishing a treatment of the reasons may find it in *Bulletin* 220 of the Ontario Department of Agriculture.

Summary of Directions for Rodding Buildings

1. Kind of Rods

Material — Copper, aluminum or galvanized iron, preferably the first because of durability. Aluminum may prove equally durable.
Combinations are not advised, because not as durable as single-metal rods.

Weight — Copper — At least 3 ounces per foot.
Aluminum — At least 2¼ ounces per foot.
Steel (Iron) — At least 4½ ounces per foot.

Form — Any form that will give *durability* and convenience of installation. Cables composed of solid wires are simple, and meet all requirements.

2. Ground Connections

Depth — Down to perpetual moisture. At least 8 feet deep.

Number — On an oblong building at least two.
On an L- or T-shaped building, at least three.
On a U-shaped building, at least four.

Location — Preferably at opposite corners, though this may be modified to avoid manure, or to go down near conductor-pipe or other metallic portion of the structure. If conductor pipe is on the side of the building, the ground rods should be at the corners as above stated, the eave-troughs connected to it, and then the conductor pipe also grounded. Always ground from the eaves.
Ground rods should not be bunched but should be distributed as well as possible.

Method — In deep soil, drill a hole at least eight feet deep, and run cable down.
In shallow soil, attach cable to metallic ground-plate, which is put down as deep in soil as possible; or run it into a well or a stream or a crevice

in the rock. If none of these are feasible, put cable as deep as possible and lay a large flat stone over it.

Caution — The owner should be present, and see that ground-connections are properly made. The rest of the system may be inspected at any time, but the groundings only when they are being put down.

3. SYSTEMS

Run Cable from ground up corner to eave, thence to ridge, along ridge to other end, thence down to eave, thence to other ground, making a complete circuit.

All cables on different portions of the same building should be connected in one system.

No stubs or dead ends should be left. All should be grounded.

Caution — Cables should be protected six or eight feet up from ground by nailing boards around them.

4. ATTACHMENTS

Fasten cable to barn with nails, staples, clips or metal "dispersers".

Caution — Do not use insulators.

5. POINTS

Number — 20 to 30 feet apart.

Location — On ridge, first and last ones not over five feet from either end.

On or beside chimneys or cupolas.

On dormers. Also on Silos.

Height — Two to five feet, except those on or beside chimneys, cupolas or similar prominences; these must extend at least eighteen inches above the highest part

Form — Strong tubes, of same weight and material as the rods.

6. METALLIC PORTIONS OF STRUCTURE

Roof gutters — Top connected to rod, and bottom grounded.

Eave-troughs and conductor-pipes — Free end of eave-troughs connected to rod and conductor-pipe grounded.

Hay-fork track — Both ends connected to rod.

Tanks — Connected to rod above, ground below.

Windmill — Connected to rod above, shaft grounded below, top of guy-wires in metallic contact with shaft, lower ends of guy-wires grounded.

Metallic roof — Grounded at two or four corners, not from peak under any circumstances. We have reports of two metal-roofed barns which were *grounded from the peak only*, being struck and burned.
Points should be used on the ridge and other prominences.

7. WIRE FENCES

In Field — A grounding at least every twenty rods.

In Yards — At the four corners.

At Building — Ground at first post from building.

Weight of Groundings — Equal to three number 12, or one number 9 wire.

Material — Same as the wire of the fence.

How Made — Stapled on posts in contact with all wires of fence and extending at least three feet into the ground, and projecting above fence in a point.

8. SHADE TREES

Should be protected where feasible.

THE SOLAR MOTION AS DETERMINED FROM THE RADIAL VELOCITIES OF SPIRAL NEBULAE

By R. K. Young and W. E. Harper

THE probability that the spiral nebulæ are independent and isolated universes and that our own universe is similar to these structures has been suggested many times. Recent observations have shown that spiral nebulæ possess radial velocities averaging several hundred kilometres a second. It seems quite possible that our own solar system and the whole universe or spiral to which it belongs may be rushing through space with a speed as yet undetermined, but of the same order of magnitude as other spiral nebulæ. Just as the observation of the velocities of stars within our universe enables us to determine the direction and speed of the sun with reference to those stars, so can observations of the velocities of nebulæ be used to determine the direction and speed of our universe, provided the data is trustworthy. The number of nebulæ for which we have velocities is, of course, very limited; but even so, the result of such a solution with the data at hand is of interest. The following velocities have been used:—

No.	Designation.	Right Ascension.		Declination.		Velocity.
		h.	m.	°	′	
1	N.G.C. 221	0	37	+ 40	19	— 300
2	N.G.C. 224	0	37	+ 40	43	— 330
3	N.G.C. 598	1	28	+ 30	09	— 278
4	N.G.C. 1068	2	38	— 0	26	+ 931
5	N.G.C. 1023	2	34	+ 38	38	+ 270
6	Nebulæ in Magellanic Clouds	4	29	— 69	46	+ 251
7	N.G.C. 3031	9	47	+ 69	32	± 000
8	N.G.C. 3115	10	00	— 7	14	+ 400
9	N.G.C. 3627	11	15	+ 13	32	+ 500
10	N.G.C. 4565	12	31	+ 26	32	+1000
11	N.G.C. 4736	12	46	+ 41	40	+ 200
12	N.G.C. 4594	12	35	— 11	03	+1000
13	N.G.C. 4826	12	51	+ 22	13	± 000
14	N.G.C. 5194	13	25	+ 47	42	± 000
15	N.G.C. 5866	15	04	+ 56	09	+ 600
16	N.G.C. 7331	22	32	+ 33	54	+ 300

Number one and two seem to be related and were combined. The nebulæ in the Magellanic Clouds are of a gaseous character, but since other investigations seem to place them at an enormous distance, it is probably legitimate to use them as a single observation. Numbers seven, thirteen and fourteen are known only to have small velocities.

The final result of the solution was:—

Right Ascension of Apex.....	20 h. 24 m.
Declination of Apex.....	— 12° 10′
Velocity of Universe.....	— 598 Km. ± 234

If we could regard the probable error as an indication of the reliability of the result, the chances are very favorable that the velocity of the universe as determined has a significance.

Prior to this note going to press, we have received a copy of *Popular Astronomy* for February, 1916, in which Mr. O. H. Truman obtains almost the same result.

Dominion Observatory,
Ottawa, Canada.
February 1, 1916.

MEETINGS OF THE SOCIETY

ANNUAL GENERAL MEETING

The Annual General Meeting of the Royal Astronomical Society of Canada was held in the Society's rooms, 198 College Street, Toronto, on the evening of January 11, 1916, First Vice-President, Dr. A. D. Watson, in the chair.

The Minutes of the Annual Meeting of 1915 as printed in the JOURNAL (February, 1915) were taken as read and approved.

The election of General Officers and Members of Council was then proceeded with. Mr. S. D. Mills and Rev. Mr. Best were appointed scrutineers. On receiving their report of the count of the ballots, the following were declared elected for the year 1916:—

Honorary President—W. F. King, C.M.G., LL.D., Chief Astronomer, Ottawa.

President—Albert D. Watson, M.D., Toronto.

First Vice-President—Allan F. Miller, Toronto.

Second Vice-President—Wm. Bruce, Hamilton.

Secretary—J. R. Collins, Toronto.

Treasurer—Charles P. Sparling, Toronto.

Recorder—W. E. W. Jackson, M.A., Toronto.

Librarian—Professor C. A. Chant, Toronto.

Curator—Robert S. Duncan, Toronto.

Council—Rev. I. J. Kavanagh, S.J., D.Sc., Montreal; Otto Klotz, LL.D., D.Sc., F.R.A.S., F.R.A.S.C., Ottawa; Rev. Dr. Marsh, F.R.A.S., Holstein, Ontario; Sir Joseph Pope, KC.M.G., Ottawa; Stuart Strathy, Toronto; Dr. W. M. Wunder, Toronto.

These, with the Past Presidents and the presiding officer of each Centre, constitute the General Council of the Society.

On motion of Mr. Collins, Mr. Dillon Mills and Mr. A. F. Hunter were appointed auditors for the 1916 accounts.

Reports from the different officers were received as follows:

GENERAL SECRETARY'S REPORT FOR THE YEAR 1915

During the year the Society has maintained itself at the various Centres without material loss as regards the number of members and the meetings held, notwithstanding the fact that quite a number of the officers and members of the Society have or are assuming military duties.

Three general Council Meetings have been held during the year.

The number of regular meetings held during the year at the several Centres and the active members attached to each are reported as follows:—

	No. of meetings held.	No. of members attached.
Toronto	17	141
Ottawa	14	93
Hamilton	7	26
Winnipeg	5	20
Guelph	7	30
Peterboro		11
Regina		16
Victoria	8	83
		420
Honorary Members		30
		450

Reports from the local Centres follow.

J. R. COLLINS,
General Secretary.

OTTAWA—LOCAL SECRETARY'S REPORT FOR 1915

During the year fourteen meetings were held by the local Centre of the Society, ten in the Spring Term and four in the Fall Term, as follows:—

EVENING MEETINGS, SPRING TERM

"The Evolution of Astronomy" (President's Address), F. A. McDiarmid.'

"The Principles of the Telescope," Prof. Bernard Gavin.

"Auroræ," Prof. C. A. Chant.

"The Spring Constellations," T. H. Parker.

Open Air Meeting, June 21.

EVENING MEETINGS, FALL TERM

"Sun Spots," Dr. R. E. DeLury.

"Companions of the Sun," Dr. Albert D. Watson.

AFTERNOON MEETINGS, SPRING TERM

"Photography," A. Steadworthy.

"Triangulation Along the British Columbia Coast," N. J. Ogilvie and G. H. McCallum.

"Wireless Telegraphy in Longitude Determinations," R. M. Stewart and W. A. Dier.

"Influence of Laplacian Points," J. E. Ratz, and "Base-Line Measurements," J. H. Moorehouse.

"The Motions of the Nearer Stars," Dr. R. K. Young.

AFTERNOON MEETINGS, FALL TERM

"Gravity," F. A. McDiarmid.

"The San Francisco Meeting of the A.A.A.S.," Dr. Otto Klotz and R. M. Motherwell.

The Evening Meetings were held in the Carnegie Public Library, the Afternoon Meetings in the Geodetic Survey Building. The lectures were of excellent character and were well attended.

During the year five new members were elected, two resigned and nine were dropped from the list, so that our membership now numbers 93. Three members are now in arrears three years. I would recommend that their names be dropped from the list.

It was moved by the Secretary that this Report be adopted; seconded by D. B. Nugent, and carried.

The Treasurer's report appears on a later page. On motion of the Treasurer, seconded by Thos. Fawcett, it was adopted.

Election of Officers for the coming year resulted as follows:

President—F. A. McDiarmid.

Vice-President—J. J. McArthur.

Secretary—E. A. Hodgson.

Treasurer—D. B. Nugent.

Councillors—Dr. W. Bell Dawson, G. B. Dodge, Thos. Fawcett.

These Officers, together with the Past Presidents, Dr. King, Dr. Klotz, Dr. Plaskett, and Mr. R. M. Stewart, constitute the Executive Board for the Ottawa Centre for the coming year.

RALPH E. DELURY,
(Retiring) *Secretary.*

HAMILTON, LOCAL SECRETARY'S REPORT FOR 1915.

The Annual Meeting of the Hamilton Centre of the Royal Astronomical Society of Canada was held on December 17, 1915.

The Secretary's and Treasurer's Reports as subjoined were read and adopted.

The Officers for the ensuing year were elected as follows:

Hon. President—Wm. Bruce.

President—J. M. Williams.

Vice-President—W. A. Robinson.

Secretary—T. H. Wingham.

Treasurer—Seneca Jones.

Council—J. J. Evel, Rev. J. J. Morton, Miss I. M. Walker.

The interest shown by the attendance seems to have about kept even with the last year. In 1913 we had one large meeting when H. B. Collier, Esq., lectured on "How I Sculptured the Moon," at which there was an attendance of 140. Last season we had no such meeting, so that our average could be a little less and yet show no falling off in interest.

There was one meeting last year at which we expected a

large attendance, viz., when Dr. Plaskett lectured on "Canada's 72-inch Reflector," but there were, unfortunately, so many attractions on the same evening that the numbers were not what we had hoped for.

There were seven meetings during the year, as follows:

December 17, 1914—"Northern Lights," Dr. Chant.
January 15, 1915—"A Trip to Labrador," J. R. Collins.
January 22, 1915—"Canada's 72-inch Reflector," Dr. Plaskett.
February 26, 1915—"1,200 Miles Down the Mackenzie," J. Patterson.
March 26, 1915—"Unsolved Problems," A. A. Hibner.
April 23, 1915—"The Solar Surface," Dr. Marsh.
May 14, 1915—"The Atmosphere," R. F. Stupart.

The average attendance at these meetings was 44.

The 3-inch telescope has been in use by two of our members.

Mr. Bruce's observatory has been open to the public during the year and a large number have availed themselves of the opportunity thus afforded them of seeing some of the wonders of the heavens.

T. H. WINGHAM,
Secretary.

WINNIPEG, LOCAL SECRETARY'S REPORT FOR 1915.

During the year 1915 five regular meetings of the Winnipeg Centre of the R.A.S.C. have been held as follows:

January 27—"The Spectroscope in Astronomy," Prof. N. B. MacLean, M.A.
February 17—"Comets as Portents," J. H. Kolb.
February 26—"Some Speculations Regarding Planetary Atmospheres," Prof. G. H. Ling, B.A., Ph.D.
November 24—"Meteors," James Duff, M.A.
December 8—"Perpetual Motion," Dr. Harold Davis, M.A.

On the last date (Dec. 8) was held the Annual Meeting at which the Officers for 1915 were ananimously elected for the year 1916, with the addition of Mr. J. W. Harris to the Council.

The Officers for 1916 are:

President—C. E. Bastin, B.A.

Vice-President—J. H. Kolb.

Secretary-Treasurer—H. R. Kingston, M.A., Ph.D.

Council—Rev. Father Blain, S.J.; Prof. N. B. MacLean, M.A.; Prof. L. A. H. Warren, M.A., F.R.A.S.; Mr. F. Powell, Mr. J. W. Harris.

The papers given during the year have been marked by serious thought, have been full of interest and very instructive. The attendance, however, has not been as great as we should desire. The Executive is putting forth increased efforts to bring in a few outside lecturers with the view to stimulating the interest in our Centre.

The comparative smallness in the number of meetings held is due to the general pressure upon everyone throughout the year, and also to the fact that in one case, at least, the plans of the Executive were frustrated at the last moment by unforeseen circumstances.

During the year this Centre has had twelve paid-up members. The prospects for the coming year are brighter, five or six new members having subscribed for 1916.

H. R. Kingston,
Secretary.

VICTORIA, LOCAL SECRETARY'S REPORT FOR 1915.

The Annual Meeting of the Victoria Centre of the R.A.S.C. was held on December 7, 1915, President A. W. McCurdy in the chair.

The election of Officers resulted as follows:

Hon. President—Dr. J. S. Plaskett.

President—Arthur W. McCurdy.

Vice-President—W. S. Drewry.

Secretary-Treasurer—Dr. F. L. Houghton.

Auditor—James Forman.

Council—F. Napier Denison, A. Symonds, J. Umbach, Rev. R. Connell, F. C. Green, George S. McTavish, K. M. Chadwick.

It was recommended that the Centre ask for a grant from the parent Society of $75.00 for the ensuing year, instead of $90.00 granted this year. It was further recommended that all members pay their dues for next year as speedily as possible in order that we may be enabled to make our returns and furnish the names of those who will be entitled to the JOURNAL for the ensuing year at an early date.

The number of members who have paid their dues for 1916 and are in good standing is 44, which is a considerable reduction in last year, due, to a great extent, to many having joined the forces. Some have already paid their dues for next year and it is hoped there will be a larger response in the coming year.

The average attendance at the meetings during the year is 55. The number of general meetings held this year is seven; four at the King's Daughters' Room in Courtney Street; one at the Gonzales Hill Observatory, and two in the Auditorium.

January 15—"The Planet Mars," Dr. L. F. Houghton.

February 16—"Evolution of the Calendar," M. Cotsworth.

March 16—"The Influence of Astronomy on our Language and Literature," J. W. Lethaby.

June 25—"Jupiter and His Moons," Dr. J. S. Plaskett. Meeting at the Observatory. Mr. F. Napier Denison showed the members his different instruments, including his new seismograph.

October 27—"Planets Jupiter and Saturn," Dr. J. S. Plaskett.

November 16—"The Sun," F. Napier Denison. The first of a series of six lectures to be given during the winter session.

December 7—Annual Meeting. "The Planet of Romance," President A. W. McCurdy.

December 21—F. Napier Denison.

The Society feels very much indebted to Mr. F. Napier Denison, who has so kindly consented to deliver a winter course of six lectures which, we trust, will be largely attended.

On motion, the Report was adopted.

L. F. HOUGHTON,
Secretary.

REGINA, LOCAL SECRETARY'S REPORT FOR THE YEAR 1915.

Fifteen members are in good standing at present.

Interest in the Society at present is not very intense. In fact, the Officers think it wise not to attempt very great things during the coming year. We are trying to arrange for four or five addresses between now and May, two by local men and the other three by outside men. As far as expenditure is concerned, we think that about $20.00 would cover everything. This would cover the expenses of the three speakers and any printing that may be found necessary.

W. G. SCRIMGEOUR,
Secretary.

GUELPH, LOCAL SECRETARY'S REPORT FOR THE YEAR 1915.

The Annual Meeting of the Guelph Centre of the R.A.S.C. was held December 29, 1915.

The following Officers were elected for the year 1916:

Hon. President—James Davison, B.A.

President—Prof. W. H. Day.

First Vice-President—H. J. B. Leadley.

Second Vice-President—Sherrif A. S. Allan.

Secretary-Treasurer—James McNiece, B.A.

Recorder—R. R. Graham, B.A., B.S.A.

Council—Mrs. J. J. Drew, Miss Mary Mills, F. A. Graesser, Lt.-Col. D. McCrea, H. Westoby, Col. John Davidson, J. M. Taylor, Sr., Col. A. H. McDonald.

R. R. GRAHAM,
Secretary.

PETERBORO, LOCAL SECRETARY'S REPORT FOR THE YEAR 1915.

At the Annual Meeting of the Peterboro Centre of the R.A.S.C., the following were elected Officers for the year 1916:

President—W. A. Logan.

Vice-President—T. A. S. Hay.

Secretary-Treasurer—T. C. Elliot.

Executive Committee—The above Officers and H. O. Fisk, D. Walker, D. Eason, H. Carveth.

We are considering the best means to arouse renewed interest in our meetings by running articles in the local papers, drawing attention to the particular constellations that may be on the meridian at the time at about nine o'clock p.m.

T. C. ELLIOT,
Secretary.

Moved by Dr. Chant, and seconded by Mr. F. Hooker, that the Secretary's Report be moved and adopted. Carried.

Moved by the Treasurer, and seconded by Mr. Collins, that the Treasurer's Report be received and adopted. Carried.

Moved by Mr. Sparling, seconded by Dr. Chant, that the financial Reports from the various Centres be handed to Council for their consideration and action. Carried.

REPORT OF THE ACTING LIBRARIAN FOR 1915.

At the last Annual Meeting, Mr. H. B. Collier was elected Librarian, and he continued his active interest in it for some months when important business matters made it necessary for him to remove to Viking, Alberta. At the request of the President, afterwards approved by the Council, I was asked to undertake the duties of the office.

Miss E. M. Budd has continued during the year as Assistant Librarian, and I feel confident in saying that the library is in as efficient condition as ever before. Our space is overtaxed, but the conditions prevailing at present will, I fear, considerably delay the securing of larger and better accommodation.

The number of periodicals received during the year is as follows:

Published in Canada and the Empire	264
Published in the United States	226
Published in other countries	74
Total	564

There were 9 books added to the library by donation and 50 by purchase, including the first 24 volumes of "The Observatory," thus completing our set.

There are several other sets of publications which we hope to complete, as this is a very important feature of the library.

During the year the library has been used perhaps more than in previous years, but the members might make considerably greater use of it. The Assistant Librarian is in attendance during each Tuesday evening meeting and on other days from 2 to 6 p.m. Members living outside of Toronto may borrow books by paying carriage on them.

The assistant librarian has endeavored to keep a complete card index of the subjects treated in the current publications received. Members desiring to consult the library will find this of valuable assistance.

JOURNALS and HANDBOOKS were sent as exchanges to 40 places in Canada and the Empire, 49 places in the United States and 24 places in other countries.

C. A. CHANT,
Acting Librarian.

Toronto, Jan. 1st, 1916.

Moved by Mr. Hooker, seconded by Rev. Mr. Best, that the Report of the Librarian be received and adopted. Carried.

The Secretary reported a communication from H. E. S. Asbury, who is at present stationed in Montreal, in which he suggests the starting of a Centre there.

Moved by Mr. Sparling, seconded by Dr. Chant, that the

thanks of the Society be extended to the scrutineers and auditors for their services. Carried.

The meeting then adjourned.

W. E. W. JACKSON,
Recording Secretary.

ANNUAL AT-HOME

The Annual At-Home of the Royal Astronomical Society of Canada, held on Tuesday evening, January 25th, 1916, in the Physics Building of the University, was well attended by the members and their friends from Toronto, and also from a number of other cities. Ottawa was represented by the retiring President, Dr. Plaskett, F. A. McDiarmid, and C. A. Bigger. Mr. T. C. Elliot represented Peterborough, Professor W. H. Day, Guelph, and T. H. Wingham and Second Vice-President Wm. Bruce represented Hamilton, whilst greetings from the Winnipeg Centre by telegram were sent by Professor Kingston of the University of Manitoba.

Dr. Albert D. Watson occupied the chair for the first time as President for 1916.

Dr. Plaskett's address on "Modern Views of the Sun" was profusely illustrated by recent photographs showing various strata of the sun's atmosphere.

After the address, a number of exhibits were shown. Views of the largest telescope in the world about to be placed in Victoria, B.C., constituted one exhibit.

Professor Day's electrical display of lightning effects, by models in operation, demonstrated vividly how clouds are attracted to the earth and why lightning may pass down a chimney and out through an open doorway and strike a person without any other lightning effects.

A spectroscope under the direction of Mr. Harry Plaskett and Mr. H. Ireton was in operation demonstrating the properties of light and many of its peculiarities.

Perhaps the most interesting and unusual of all was the beautiful production of an artificial "Mirage" by Messrs. Gilchrist and Henderson. This startling effect was produced over a number of heated metal plates covered with sand, on the surface of which were placed miniature objects representing views to be met with on the desert. When the observer's eye was brought to the level of this heated artificial desert and directed towards a bright screen beyond it, the objects on its surface appeared, in a perfect and beautiful manner, to leap in the air and remain inverted and in different positions as the air currents were disturbed, just as they were known to do in a natural mirage.

Regarding the "Modern Views of the Sun," Dr. Plaskett, the lecturer, showed in a non-technical way, how present-day views of the constitution of the sun had been developed principally by the spectroscope and its auxiliary, the spectroheliograph. These have supplemented visual observations and show the sun to be an immense magnet with poles near its north and south points 80 times stronger than the magnetism of the earth; and further, that every sun-spot is the centre of a strong magnetic field, and that these influence the magnetism of the earth. It was shown that sun spots are probably a kind of tornado from below upwards and outwards, drawing in the outer gases very much like a water spout. As the temperature of the sun's surface is about 12,000 degrees F., it is likely that the sun is wholly gaseous. It would require the burning of a layer of coal covering the sun's surface 23 feet thick every hour, to maintain its present temperature. It is believed that the shrinkage of its mass about 250 feet yearly would produce that amount of heat. Under these conditions the sun probably can maintain the present output of heat for 7,000,000 years, and probably has not done so for more than 25,000,000 years past. The problem of the reconcilaition of this period with the longer period demanded by geologists for the earth to reach its present condition remains unsolved. The address is printed in full in this issue (see page 101).

FINANCIAL STATEMENT, JANUARY 1st TO DECEMBER 31st, 1915.

RECEIPTS

Jan. 1	Cash in Imperial Bank	$2 232.07	
	Grant from Ontario Legislature	600.00	
	Grant from Dominion Government	2 000.00	
	Grant from City of Toronto	100.00	
	University Governors for JOURNALS	100.00	
	Fees from Members	751.80	
	Interest on Deposits	55.15	
	Exchange on Plaskett Cheque	.15	
			$5 839.17

DISBURSEMENTS

Publication of JOURNAL and HANDBOOK	2,602.58	
Public Meetings	114.57	
Library	215.81	
Furnishing Typewriter	50.00	
Stationery and Postage Stamps	33.02	
Lantern Slides	10.65	
Salaries—Assistant Librarian, etc.	310.00	
Insurance on Library	13.00	
Rent	200.00	
Building Fund Bond in C.P.L & S.	300.00	
Grant to Ottawa Centre	100.00	
Grant to Hamilton Centre	60.00	
Grant to Victoria Centre	90.00	
Grant to Regina Centre	50.00	
Grant to Winnipeg Centre	50.00	
Lantern to Victoria Centre	42.75	
Cash Balance in Bank	1,596.79	
		$5 839.17

CASH ASSETS, JANUARY, 1916.

Bonds in Bank	$1 872.40	
Cash in Savings Dept.	92.12	
Cash in General Account	1 596.79	
		$3 561.31

Respectfully submitted,
CHAS. P. SPARLING,
General Treasurer.

Audited and found correct,
A. F. HUNTER,
W. E. W. JACKSON,
Auditors.
Toronto, January 1st, 1916.

OTTAWA CENTRE

Financial Statement, 1915

RECEIPTS

Balance on hand	$ 22.77	
Annual Grant	100.00	
Interest	1.50	
		$124.27

EXPENDITURES

Lectures	$ 53.00	
Printing	38.00	
Postage	11.10	
Cartage	2.00	
Sundries	4.46	
	108.56	
Cash in Bank	15.71	
		$124.27

Respectfully submitted,
D. B. Nugent,
Local Treasurer.

Examined and found correct,
(Signed) D. Robertson,
W. S. McClenahan.

HAMILTON CENTRE

Financial Statement, 1914-1915

RECEIPTS

Dec. 17, To Balance, 1914	$ 43.21	
Jan. 6, To Fees	2.00	
May 11, To Annual Grant, R.A.S. of Canada	60.00	
		$105.21

EXPENDITURES

Dec. 21, By Lecture Expenses	$ 4.53	
1915.		
Jan. 23, By Lecture Expenses	3.78	
Feb. 13, By Lecture Expenses	5.00	
Mar. 13, By Lecture Expenses	4.03	
Apr. 24, By Lecture Expenses	7.80	
May 25, By Lecture Expenses	5.30	
	$ 30.44	
Jan. 6, By Fees Remitted to Toronto	8.00	
Mar. 25 and Apr. 24, By Printing	14.00	
Dec. 6, By Balance in Bank	52.77	
		$105.21

(Sgd.) Seneca Jones,
Treasurer.

Audited and found correct,
(Sgd.) W. A. Robinson.
10th December, 1915.

WINNIPEG CENTRE

FINANCIAL STATEMENT, 1915

RECEIPTS

1914.			
Dec. 1,	To Balance	$113.59	
Dec. 7,	To Subscription (1915), Rev. Father Blain	2.00	
1915.			
Jan. 12,	To Interest (Nov. 31, 1914)	1.72	
Jan. 12,	To Interest	.25	
Jan. 12,	To Subscription, Mr. A. V. Franklin	2.00	
	To Subscription, Mr. C. E. Bastin	2.00	
	To Subscription, Prof. L. A. H. Warren	2.00	
	To Subscription, Dr. Wilson	2.00	
	To Subscription, Mr. J. H. Kolb	2.00	
	To Subscription, Mr. L. H. Bennett	2.00	
	To Subscription, Dr. H. R. Kingston	2.00	
Feb. 26,	To Subscription, Prof. N. B. MacLean	2.00	
Feb. 26,	To Subscription, Mr. F. Powell	2.00	
Apr. 14,	To Subscription, Mrs. E. C. Mitchell	2.00	
Apr. 15,	To Subscription, Mr. J. W. Harris	2.00	
May 31,	To Interest	.50	
Oct. 27,	To Grant from Toronto	50.00	
Nov. 24,	To Subscription (1916), Mr. J. H. Pickering	2.00	
Dec. 2,	To Subscription (1916), Mr. O. Schumacher	2.00	
	Total		$194.06

EXPENDITURES

1914.			
Dec. 2,	By Lantern Slides (J. Carmichael)	$ 5.25	
Dec. 2,	By Caretaker (W. H. Peake)	5.00	
Dec. 2,	By Caretaker (J. Buchanan)	5.00	
1915.			
Jan. 30,	By Printing (Free Press)	6.25	
Feb. 9,	By Remittance to Toronto	16.00	
Feb. 9,	By Exchange on same	.15	
Feb. 19,	By Telegram (Saskatoon)	.60	
Mar. 2,	By Printing	5.00	
Mar. 2,	By Stamps	.40	
Mar. 8,	By Dr. G. H. Ling (expenses Saskatoon to Winnipeg)	40.40	
Mar. 8,	By Exchange on same	.15	
May 6,	By Remittance to Toronto	8.00	
May 6,	By Exchange on same	.15	
Oct. 30,	By Exchange on Grant from Toronto	.15	
Nov. 3,	By Stamps	1.00	
Dec. 3,	By Printing	4.00	
	Total	97.50	
Dec. 8,	By Balance on Hand	96.56	
			$194.06

H. R. KINGSTON,
Treasurer.

Audited and found correct,
(Signed) FRANK POWELL.
December 8th, 1915.

VICTORIA, B.C., CENTRE

Financial Statement, 1915

RECEIPTS

Fees from 44 members for 1915	$ 88.00	
Fees from 11 members for 1916	22.00	
	110.00	
Grant from Parent Society	90.00	
Received for copy of Journal	.25	
		$200.25

EXPENDITURE

Remittance to General Treasurer, Sept. 11, 1915	$ 82.00	
Margison Bros. (P.C.'s and Printing)	19.75	
Stenographer	2.00	
Post Cards	.50	
Colonist (Printing	3.25	
Newton Advertising Agency (Multigraphing)	1.80	
Miss Leitch (Hire of Hall)	15.00	
Hire of Lantern and Operator	18.00	
Receipt Book and Cash Book	.75	
Stamps	4.00	
Sundry small payments	7.25	
Bank Commission on cheques	.25	
Balance to Credit	45.70	
		$200.25

Audited and found correct,
W. M. Darby,
Auditor.

REGINA CENTRE

Financial Statement, 1915

RECEIPTS

Balance as per audited statement, Dec. 7, 1914	$15.61	
Interest	.15	
Grant from General Society	50.00	
Interest, May 31 and Nov. 30	.80	
		$ 66.56

EXPENDITURE

Exchange on Check from Gen. Society	$ .20	
Oct. 16, Fees to General Society	64.00	
Oct. 16, P.O. Order for above	.25	
	$64.45	
Dec. 31, 1915, Balance	2.11	
		$ 66.56

W. G. Scrimgeour,
Secretary-Treasurer.

Audited and found correct,
J. E. Campbell.
January 14, 1916.

PETERBOROUGH CENTRE

Financial Statement, 1915

RECEIPTS

Balance from 1914	$ 80.20	
Members' Fees	22.00	
		$102.20

EXPENDITURES

Fees	$ 22.00	
Postage	2.00	
Expense of Lecturers	15.50	
Express on Globes	1.39	
Caretaker	4.00	
Commission on Cheque	.15	
	45.04	
Balance in Bank	54.55	
Balance in Petty Cash	2.61	
		$102.20

T. C. Elliot,
Secretary-Treasurer.

GUELPH CENTRE

Financial Statement, 1915

RECEIPTS

Balance on hand January 1st, 1915.....	$145.62	
Members' Fees for 1915.....	56.00	
Members' Arrears for 1913 and 1914....	22.00	
Interest on Bank Account.....	4.58	
		$228.20

EXPENDITURES

Remittance to General Treasurer as Members' Fees	$ 78.00	
Rent for Lecture Hall.....	12.00	
Caretaker of Hall.....	6.00	
Printing, Advertising and Postage.....	22.25	
Travelling Expenses of Lecturers.....	22.85	
Cartage on Lantern for Lecturer.....	3.50	
Cash on hand.....	83.60	
		$228.20

R. R. Graham,
Treasurer.

Audited and found correct,
H. J. B. Leadlay,
Auditor.
January 3rd, 1916.

NOTES FROM THE METEOROLOGICAL SERVICE

Summary Report of the Weather in Canada

January, 1916

Temperature.—A line drawn north and south through the middle of Lake Superior is very nearly the dividing line between mean temperatures above normal in the east, and below normal in the west. From Manitoba westward the negative departures increased rapidly from 3° at Winnipeg to 24° at Medicine Hat, and nearly 30° in the Upper Mainland of British Columbia, and thence lessened again to 10° near the coast. These negative departures in British Columbia and Alberta are the largest on record. The largest positive departures ranging between 6° and 9° occurred in Southern and Eastern Ontario, whence they diminished eastward to the Maritime Provinces, where the temperature was very nearly normal.

Precipitation.—Precipitation was below the normal in British Columbia and in the Maritime Provinces, while in the Western Provinces and nearly all parts of Ontario and Quebec it was considerably in excess. The greatest positive departures were in Northern Ontario and in the vicinity of Winnipeg, where there were some unusually heavy snowfalls. The largest negative departure was in Cape Breton, where the total fall was only about one-third of the average for January. The snowfall has been excessive in British Columbia, especially near the Coast, where the ground had an unusually deep covering on the 31st, which has since been greatly augmented. An unusually large amount of

snow also covered the Prairie Provinces, the depth ranging from about seven inches in the vicinity of Calgary to over two feet in many parts of Eastern Saskatchewan and Manitoba. The frequent strong winds caused considerable drifting, and the roads and trails in many places became heavy and rather difficult to travel.

Depth of Snow.—In Ontario the snow was from two to four feet over the Thunder Bay, Rainy River and Algoma districts, and in the Upper Ottawa Valley it was from eighteen to twenty-four inches, while in the peninsula and the counties contiguous to Lake Ontario the ground was entirely bare. In southwestern Quebec there was very little snow at the close of the month, but in the counties to the northward of the Ottawa River and farther east in the province it was quite deep, amounting to two feet or over. In the Northern Interior counties of New Brunswick the snow was also quite deep, and Prince Edward Island was covered to a depth of six or seven inches, while in Nova Scotia the ground was bare in many places and traces remained in others.

Temperature for January, 1916

Station	January		Station	January	
	Highest	Lowest		Highest	Lowest
Yukon			Huntsville	49	20
Dawson	20	-58	Kenora	20	-44
British Columbia			Kinmount	44	-12
Atlin	31	-42	Kingston	44	- 7
Agassiz	42	- 2	London	57	- 4
Barkerville	21	-40	Lucknow	57	- 3
Kamloops	32	-28	Markdale	48	- 5
New Westminster	44	1	North Gower		
Prince Rupert	44	- 6	Oshawa	49	-24
Vancouver	44	6	Ottawa	44	-16
Victoria	48	15	Paris	54	- 1
Western Provinces			Parry Sound	46	-10
Battleford	20	-61	Peterboro'	50	-11
Calgary	36	-41	Port Arthur	34	-26
Edmonton	29	-45	Port Burwell	50	1
Medicine Hat	30	-48	Port Dover	50	2
Minnedosa	20	-38	Port Stanley	48	2
Moose Jaw	22	-53	Queensborough	45	-18
Oakbank	22	-46	Ronville	48	-18
Portage la Prairie			Southampton	59	1
Prince Albert	16	-58	Sundridge	49	-29
Qu'Appelle	20	-46	Stonecliffe	44	-25
Regina	13	-53	Stony Creek	59	1
Saskatoon	17	-51	Toronto	53	1
Souris	20	-48	Uxbridge	49	- 8
Swift Current	28	-48	Wallaceburg	57	- 1
Winnipeg	22	-40	Welland	60	- 1
Ontario			White River	38	52
Agincourt	52	- 2	*Quebec*		
Aurora	48	- 6	Brome	52	-24
Bancroft			Father Point	42	-10
Barrie	52	- 9	Montreal	46	- 6
Beatrice	48	-18	Quebec	44	-18
Berlin	54	- 0	Sherbrooke	49	-18
Bloomfield	51	0	*Maritime Provinces*		
Brantford			Charlottetown	42	- 8
Chapleau	58	-42	Chatham	44	-12
Chatham	59	1	Dalhousie	41	-15
Clinton	58	3	Fredericton	47	-15
Collingwood	51	0	Halifax	54	- 4
Cottam	60	- 2	Moncton	50	-11
Georgetown	51	0	St. John	45	- 1
Goderich			St. Stephen		
Gravenhurst	46	-28	Sussex	48	-11
Grimsby	60	- 2	Syndey	46	- 2
Guelph	54	1	Yarmouth	45	5
Haliburton	36	-13			

MAGNETIC OBSERVATIONS

JANUARY, 1916

During tne month of January the magnetic records obtained at Agincourt indicate more than usual quiescence in the Magnetic Forces. On 14 days they are classified as calm. A fairly large disturbance which began on the 10th was quite active during the 11th and continued during the 12th. Although the amplitude of the oscillations was not excessive, yet the maximum and minimum for the month occurred during this disturbance.

Light disturbances occurred on the 4th, 5th, 16th, from the 20th to the 26th, on the 29th and 31st.

Auroræ were recorded on the 11th in all parts of Canada, and on the 22nd in Northern Ontario and on a few other dates only in a few places.

January, 1916		D. West	H	V	I
		° ′			° ′
	Mean of Month	6 30·9	0·15997	0·58554	74 43·2
	Maximum	6 53·2	0·16092	0·58705	74 51·3
	Date of Maximum	11	11	11	11
	Minimum	5 55·2	0·15858	0·58538	74 39·0
	Date of Minimum	12	11	11	22
	Monthly Range	0 58·0	0·00234	0·00204	
Mean Daily Amplitude	From hourly readings	0 7·8	0·00029	0·00008	
	From Means of Extremes	0 15·8	0·00060	0·00022	

W. E. W. J.

Earthquake Records by the Milne Seismograph

TORONTO

R. F. Stupart, Director.

P.T. = Preliminary Tremors. L.W. = Large Waves. A.C. = Air Currents.
Time is Greenwich Civil Mean Time, 0 or 24 h = midnight.

No.	Date 1916		P. T. Comm.	L.W. Comm.	Max.	End	Max. Amp.	Durat.	Remarks
			h m	h m	h m	h m	mm.	h m	
1542	Jan.	1	13 39·9 S 13 48·3 13 55·7?	13 57·4 13 58·0	14 32·8	Small vibs. going on when paper changes at 17 25	over 40·0		Very large disturbance.
1543	"	11		12 25·8	12 30·0	12 43·6	0·3		
1544	"	13	6 50·6 S 6 57·4	7 9·3	7 39·9		6·5		Medium disturbance.
1545	"	13		9 0·2	9 44·3		8·3		Trailers merged
1546	"	13		10 31·0	10 36·3		8·0		into P and S
1547	"	13		12 7·4	12 12·5	13 31·7	0·5		phases.
1548	"	19	19 51·0 S 19 55·3	20 3·4	20 9·1	20 50·5	1·6	0 59·5	
1549	"	24	7 13·7? S 7 17·9	7 23·5	7 46·7	9 39·3	1·8	2 25·6	Repeat 9h 26m·2 to 9h 39m·3. May be two quakes.
1550	"	26		8 0·0 8 11·0	8 17·7	8 45·0	0·2		
1551	"	26	12 53·1?	13 00·0? 13 21·8	13 26·9	14 12·0?	1·3	1 18·9	
1552	"	30		21 31·8 21 34·1	21 42·6	22 12·1	0·3		
1553	"	31	attending inst. S 18 20·2	18 31·6	18 44·1	20 2·9	1·7		Repeat 19h 33m·8 to 19h 37m·8. Amp 0·2 mm.

Period 18 seconds. 1 mm. = 0″·50.

VICTORIA, B. C.

F. N. DENISON, SUPERINTENDENT.

No.	Date 1916	P.T. Comm.	L.W. Comm.	Max.	End	Max. Amp.	Durat.	Remarks
		h m	h m	h m	h m	mm.	h m	
1547	Jan. 1	13 33·4 S13 44·8	14 1·5	14 12·6	18 58·5	over 31·0	5 25·1	A large disturbance. 12,460 km.
1548	" 11	11 58·9? S12 2·9	12 5·9	12 7·4	12 29·9	0·3	0 31·0	2,440 km.
1549	" 13	6 43·5 S 6 51·5	7 7·0	7 19·1	merged into next quake.	5·5		6,430 km.
1550	" 13	8 33·0? S 8 45·5?	9 6·5	9 27·0		5·5		12,250 km.
1551	" 13	S10 29·9?	10 36·7	10 48·8		1·3		
1552	" 13		11 42·7	11 47·9	12 12·0	0·3		
1553	" 19	19 40·5? S19 42·9	19 45·4	19 47·9	20 22·1	1·5	0 41·6	
1554	" 24	S 7 19·0?	7 33·9	7 49·1	8 44·8	1·0		
1555	" 24	9 25·5	9 28·9	9 31·4	9 40·8	0 2	0 15·3	
1556	" 26	8 21·0 S 8 23·5	8 24·9	8 25·4	8 39·8	0·2	0 18·8	
1557	" 26	12 48·9? 12 52·9	13 10·5	13 16·5	13 47·7	0·5	0 45·6	

No returns in from Victoria after the 29th.

Period 18 seconds. 1 mm. = 0″·54

J. V.

ASTRONOMICAL NOTES

THEORY OF STAR-STREAMING AND THE STRUCTURE OF THE UNIVERSE.—(SUMMARY AND CONCLUSION).— In the first part of this paper we examined under what conditions Schwarzschild's ellipsoidal law was possible in a universe in a steady state. A true ellipsoidal law was found to be possible only in a universe which is of spherical shape. When the universe is not spherical, but possesses symmetry about an axis, the Schwarzschild ellipsoid degenerates into a spheroid, the two axes in the meridional plane of the universe becoming equal. In all other cases, except possibly a few special and highly artificial ones, this ellipsoid reduces to a sphere, so that the proper motions of the stars occur in all directions equally, and there can be no star-streaming.

In the second part of the paper the restriction to laws of ellipsoidal form was abandoned, and an attempt was made to discover the most general law of distribution which can be consistent with a steady state. In general, when a star moves under the gravitational influence of the whole remainder of the universe, there will be only one first integral of its equations of motion independent of the time, namely, the energy integral. When this is the case, it is found that the velocity diagram for every region in space must reduce to a sphere, so that there can be no star-streaming anywhere. Thus, if star-streaming is observed in a universe which is supposed to be in a steady state, it can only be because every star has, in addition to the energy integral, another first integral which is independent of the time.

Except for highly artificial arrangements, such as are hardly likely to have any relations to actuality, additional first integrals can only be obtained by supposing the universe to have at least one axis of symmetry of figure. Our universe may with some confidence be supposed not to be spherical, so that the only case of importance to us is that of a universe shaped like a figure of revolution. In such a universe there is always one additional first integral, namely, an integral expressing constancy of the moment of momentum about the axis of the universe. In such a universe we found the most general law of distribution of velocities which could be consistent with the existence of a steady state. This law

was found to be consistent with the existence of star-streaming, although not of star-streaming of the kind which is observed in our own universe. Thus even if our universe may legitimately be thought of as possessing symmetry about an axis of revolution, it appears that star-streaming such as is observed in our universe does not seem to be consistent with the supposition that our universe is in a steady state.

In the third section of this paper, we examined the condition that the different parts of a universe should be dynamically in equilibrium. It was found that a universe in which the velocity diagram is everywhere spherical can only be in equilibrium when its own shape is spherical. It was found that the only universe which can be in equilibrium in a shape other than spherical is one in which star-streaming occurs in circles around the axis of the universe, the universe itself being symmetrical about this axis. It is doubtful whether our universe may legitimately be supposed to have this kind of symmetry, but in any case the observed star-streaming is not of the kind required, so that we have to suppose that our universe cannot be dynamically in a state of equilibrium.

We are therefore compelled to give up all hope of unravelling the mechanism of our universe by assuming that it is in a steady state, and using the phenomenon of star-streaming as a means of exploring its structure. It ought perhaps to be noticed that there was never any valid reason for supposing that we should arrive at the truth by making the assumption that the universe is in a steady state. Indeed, the *a priori* probabilities are all in the other direction. The direct observational knowledge which we have of the movements in our universe is excessively limited both in time and space: the introduction of the steady-state hypothesis is only a tentative effort to remove the restriction in time. In the same way a being whose life was infinitely more restricted than ours might try if he could explain such phenomenon as an earthquake or a lightning flash in terms of a steady-state hypothesis. His attempts, as we know, would be foredoomed to failure, and the results we have obtained seem to indicate that attempts to explain star streaming as a steady-state phenomenon must be equally foredoomed to failure. It appears that we must not read into star-streaming anything more than we can actually see, or perhaps at most we may regard it as a motion of parts of the universe which are in process of taking up the positions or motions they will ultimately have in some future steady state which has not yet been attained.—J. H. JEANS, *Monthly Notices R. A. S.*, December, 1915. J. R. C.

NOTES AND QUERIES

Communications are Invited, Especially from Amateurs. The Editor will try to Secure Answers to Queries.

I. Query

The Editor has received a request for information on the constellations adapted to beginners in Astronomy; and along with the request was an intimation that the Journal was not doing its duty in failing to publish such matter from month to month.

Answer

In reply, the Editor would state that he has sincere sympathy with the beginner in Astronomy and he also thinks it best to commence with the constellations; but he does not believe that the Journal is the most suitable medium for conveying the information desired by one who is entering on a study of the sky. There has already been outlined in this department a convenient way to go about the pleasant task of identifying the various star groups, and brief articles dealing with the objects to be seen in the sky at special times have been, and will continue to be, published. In the Handbook is given a brief sketch of the constellations, together with a very usable set of maps. That is about as far as we can reasonably go in the matter of the constellations. It would be unwise to supply all the little details and instructions which the amateur desires in order to observe certain stars, especially when numerous manuals are obtainable which deal with the subject much better than we could hope to do. Moreover, the constellations are the same year after year and it would be a great waste to print the same extended matter over and over again in the Journal. This has to a limited extent to be done in the Handbook,

which, in addition, contains the positions of the sun and the planets every month (which may be transferred to the star maps, thus following their paths in the sky), also the various conjunctions of the planets, information regarding eclipses, occultations, satellites, etc. It is indeed what its name indicates,—a book to have constantly at your hand for reference—and it is of a size convenient to slip into the pocket.

Among desirable books for the student of the stars may be mentioned:

A Beginner's Star-Book, by Kelvin McKready, published by Putnam's, N.Y., 1912. Price, $2.75.

This book is 7½ x 10 inches in size, contains many fine illustrations, is beautifully illustrated, and contains detailed instructions for use with an opera-glass, a two-inch and a three-inch telescope. It is an ideal book for the working amateur.

Astronomy With An Opera-Glass, by G. P. Serviss, published about 1890 by Harper's. Price, $1.50.

This book is excellent, though not so finely illustrated or so full of information as the previous one.

Star Lore of All Ages, by W. T. Olcott. 8vo. Published by Putnam's, N.Y. Price, $3.50.

This book has diagrams and a good description of each constellation, is finely illustrated by reproductions of many famous paintings and sculptures and contains numerous references to the old mythology.

II. Query

In the Journal orbits of spectroscopic binaries are continually being published. Can you give an article explaining the significance of these? —T. H. W.

Answer

An article by Dr. R. K. Young on this subject was published in volume V., page 335 (Nov.-Dec., 1911).

III. Query

Can you give the name of any book dealing at some length with the Nebulæ?—Toronto Member.

Answer

I think the best systematic treatment of Nebulæ is to be found in Clerke's *Problems in Astrophysics*. This book was published in 1903 and so is not up-to-date, but the only way to get an account of the recent work is by reading the various astronomical periodicals, our Journal included.

THE SOLAR ECLIPSE OF FEBRUARY 3, AND TAYLOR'S COMET

Harvard Bulletin, No. 598, gives the following cablegram received from Perrine, Director of the Argentine National Observatory, Cordoba:

"Argentine expedition Venezuela announces observation total solar eclipse through thin clouds."

Bulletin No. 599 is from Frost, Director of the Yerkes Observatory, and is as follows:

"Barnard finds Taylor's Comet has double nucleus distance 10″, position angle 21° at 7h. 30m. C. T., February 9, magnitudes about 14 and 15."

C. A. C.